

Claims

- [c1] 1. A method of producing high quality semi-insulating silicon carbide crystals in the absence of relevant amounts of deep level trapping elements, the method comprising:
- heating a silicon carbide crystal having a first concentration of point defect related deep level states to a temperature above the temperatures required for CVD growth of silicon carbide from source gases, but less than the sublimation temperature of silicon carbide under the ambient conditions to thereby thermodynamically increase the concentration of point defects and resulting states in the crystal; and
- cooling the heated crystal to approach room temperature at a sufficiently rapid rate to maintain a concentration of point defects in the cooled crystal that remains greater than the first concentration.
- [c2] 2. A method according to Claim 1 comprising heating and cooling a crystal to increase the number of point defects to an amount that exceeds the concentration of uncompensated dopants.
- [c3] 3. The semi-insulating silicon carbide crystal made by the method of Claim 1.
- [c4] 4. A method according to Claim 1 comprising heating a single crystal silicon carbide wafer.
- [c5] 5. A method according to Claim 1 comprising heating a single crystal silicon carbide boule.
- [c6] 6. A method according to Claim 1 comprising heating a crystal that has a polytype selected from the 3C, 4H, 6H and 15R polytypes of silicon carbide.
- [c7] 7. A method of producing a semiconductor device precursor comprising growing a silicon carbide epitaxial layer on a semi-insulating silicon carbide substrate produced by the method of Claim 1.
- [c8] 8. A method according to Claim 1 comprising heating and cooling a compensated silicon carbide crystal.

- [c9] 9. A method according to Claim 7 comprising heating and cooling a compensated crystal in which the most concentrated dopant is present in an amount of about $5E16$ or less.
- [c10] 10. A method according to Claim 1 comprising cooling the heated crystal to room temperature.
- [c11] 11. A method of producing semi-insulating resistivity in silicon carbide, the method comprising:
heating a silicon carbide single crystal to a temperature of at least about 2000°C to thereby thermodynamically increase the number of point defects and resulting deep level states in the crystal; and
cooling the heated crystal to approach room temperature at a sufficiently rapid rate to maintain a concentration of point defects in the cooled crystal that remains greater than the first concentration.
- [c12] 12. The semi-insulating silicon carbide crystal made by the method of Claim 11.
- [c13] 13. A semi-insulating silicon carbide crystal according to Claim 12 having a polytype selected from the group consisting of the 3C, 4H, 6H, and 15R polytypes of silicon carbide.
- [c14] 14. A method according to Claim 11 comprising cooling the crystal to room temperature.
- [c15] 15. A method according to Claim 11 comprising heating the crystal to a temperature of between about 2000°C and 2400°C at atmospheric pressure.
- [c16] 16. A method according to Claim 11 comprising cooling the crystal at a rate of between about 30° and 150°C per minute.
- [c17] 17. A method according to Claim 16 comprising cooling the crystal to 1200°C or less.
- [c18] 18. A method according to Claim 11 comprising heating a boule of silicon carbide.
- [c19] 19. A method according to Claim 11 comprising heating a silicon carbide wafer.

- [c20] 20. A method according to Claim 11 comprising heating the crystal for at least two minutes.
- [c21] 21. A method according to Claim 11 wherein the step of heating the crystal comprises heating the crystal in an induction heater, and the step of cooling the crystal comprises reducing the power to the induction coil.
- [c22] 22. A method according to Claim 21 wherein the cooling step further comprises contacting the crystal with a coolant.
- [c23] 23. A method according to Claim 11 or Claim 22 wherein the step of cooling the crystal comprises flooding the ambient surroundings with an inert gas.
- [c24] 24. A method according to Claim 11 wherein the step of cooling the crystal comprises controlling the thermal mass in the ambient surroundings.
- [c25] 25. A method according to Claim 15 comprising cooling the crystal to about room temperature in less than 70 minutes.
- [c26] 26. A method according to Claim 15 comprising cooling the crystal to about room temperature in less than 20 minutes.
- [c27] 27. A method of producing semiconductor device precursors on semi-insulating substrates, the method comprising:
heating a silicon carbide substrate wafer to a temperature of at least about 2000 ° C;
cooling the heated wafer to 1200 ° C or less at a rate of at least about 30 ° C per minute; and
depositing an epitaxial layer of a semiconductor material on the substrate wafer.
- [c28] 28. The wafer and epitaxial layer produced by the method of Claim 27.
- [c29] 29. A method according to Claim 27 wherein the step of cooling the heated wafer comprises cooling the heated wafer to approach room temperature.
- [c30] 30. A method according to Claim 27 wherein the step of depositing the epitaxial

layer comprises depositing a layer selected from the group consisting of silicon carbide and Group III nitrides.

- [c31] 31. A method according to Claim 27 comprising depositing an epitaxial layer of silicon carbide by chemical vapor deposition while maintaining the wafer at a temperature of about 1400 ° C or greater.
- [c32] 32. A method according to Claim 27 comprising heating the wafer to a temperature of between about 2000 ° C and 2400 ° C at atmospheric pressure.
- [c33] 33. A method according to Claim 27 comprising cooling the wafer at a rate of between about 30 ° and 150 ° C per minute.
- [c34] 34. A method according to Claim 27 wherein the step of cooling the wafer comprises flooding the ambient surroundings with an inert gas.
- [c35] 35. A method according to Claim 27 wherein the step of cooling the wafer comprises controlling the thermal mass in the ambient surroundings.
- [c36] 36. A method according to Claim 27 comprising cooling the wafer to about room temperature in less than 70 minutes.
- [c37] 37. A method according to Claim 27 comprising cooling the wafer to about room temperature in less than 20 minutes.
- [c38] 38. A method of producing semiconductor device precursors on semi-insulating substrates, the method comprising:
heating a silicon carbide boule to a temperature of at least about 2000 ° C;
cooling the heated boule to approach room temperature at a rate of at least about 30 ° C per minute;
slicing a silicon carbide wafer from the boule ; and
depositing an epitaxial layer of a semiconductor material on the sliced wafer.
- [c39] 39. A wafer and epitaxial layer thereon formed by the method of Claim 38.
- [c40] 40. A device that incorporates the wafer and epitaxial layer according to Claim 39.

- [c41] 41. A device according to Claim 40 selected from the group consisting of FET"s, MOSFET"s, JFET"s, MESFET"s, HFET"s, HEMT"s, DMOS FET"s, extended drain MOSFET"s; vertical DMOS transistors, and lateral DMOS transistors.
- [c42] 42. A method according to Claim 38 comprising heating the boule to a temperature of between about 2000 ° C and 2400 ° C at atmospheric pressure.
- [c43] 43. A method according to Claim 38 comprising cooling the boule at a rate of between about 30 ° and 150 ° C per minute.
- [c44] 44. A method according to Claim 43 comprising cooling the boule to 1200 ° C or less.
- [c45] 45. A method according to Claim 38 comprising depositing an epitaxial layer of silicon carbide by chemical vapor deposition while maintaining the wafer at a temperature of about 1400 ° C or greater.
- [c46] 46. A method of producing semiconductor device precursors on semi-insulating substrates, the method comprising:
slicing a silicon carbide wafer from a single crystal silicon carbide boule;
heating the sliced wafer to a temperature of at least about 2000 ° C;
cooling the heated wafer to approach room temperature at a rate of at least about 30 ° C per minute; and
depositing an epitaxial layer of a semiconductor material on the sliced wafer.
- [c47] 47. A wafer and epitaxial layer thereon formed by the method of Claim 46.
- [c48] 48. A device that incorporates the wafer and epitaxial layer according to Claim 47.
- [c49] 49. A device according to Claim 48 selected from the group consisting of FET"s, MOSFET"s, JFET"s, MESFET"s, HFET"s, HEMT"s, DMOS FET"s, extended drain MOSFET"s; vertical DMOS transistors, and lateral DMOS transistors.
- [c50] 50. A method according to Claim 46 comprising heating the sliced wafer to a temperature of between about 2000 ° C and 2400 ° C at atmospheric pressure.
- [c51] 51. A method according to Claim 46 comprising cooling the wafer at a rate of

between about 30 ° and 150 ° C per minute.

[c52] 52. A method according to Claim 47 comprising cooling the wafer to 1200 ° C or less.

[c53] 53. A method according to Claim 46 comprising depositing an epitaxial layer of silicon carbide by chemical vapor deposition while maintaining the wafer at a temperature of about 1400 ° C or greater.

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